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M. W. HARRINGTON,
Director of the Astronomical Observatory, Ann Arbor, Michigan,
A. LAWRENCE ROTCH,
Proprietor of the Blue Hill Meteorological Observatory, Massachusetts.
Editors.
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THE AMERICAN
METEOROLOGICAL JOURNAL.

VOL. V. ANN ARBOR, JUNE, 1888. No. 2.

ORIGINAL ARTICLES.

THE ORGANIZATION OF THE METEOROLOGICAL SERVICE IN SOME OF THE PRINCIPAL COUNTRIES OF EUROPE.

BY A. LAWRENCE ROTCH,
Member of the German Meteorological Society, and Fellow of the Royal (London) Meteorological Society.

AUSTRIA.

History.—Meteorological observations had been made in Austria, as in most of the other countries of Europe, in the last century, chiefly by the astronomical observatories. In the beginning of the present century a number of stations were making regular meteorological observations, and to these and to the observations of terrestrial magnetism, Kreil, the director of the observatory of Prague, devoted much attention. By his efforts, the Imperial Academy of Science in Vienna undertook the management of this system of stations through a director appointed by its commission. Thus, in 1851, was organized the *K. K. Central Anstalt für Meteorologie und Erdmagnetismus,* with Kreil as its director. The central office was established in Wieden, a suburb of Vienna, where it remained until transferred in 1872 to the new building on the Hohewarte in the suburb Döbling. In 1867, Jelinek, who had succeeded to the direction on Kreil's death, extended the facilities of the central office, both in space and appropriation. At Jelinek's decease in 1877,

Prof. Hann, his former assistant, became director, and his ability and reputation have made the *Central Anstalt* a model among the meteorological institutions of Europe.

Organization.—The system consists chiefly of volunteer observers under the superintendence of a central office maintained by the Minister of Instruction. Originally, the meteorological stations reporting to the Central Institute embraced all those in the Austro-Hungarian monarchy, but since 1871 the Hungarian countries (Hungary, Transylvania, Croatia and Slavonia) have had an independent system managed by a central office at Buda-Pesth. Besides the central office at Vienna there are certain independent astronomical observatories and schools which make meteorology and terrestrial magnetism secondary to their regular work, and publish the observations. These are the astronomical observatories of Cracow, Kremsmünster and Prague, the Hydrographic Office in Pola, and the Nautical and Commercial Academy in Trieste, which will be described in detail later. The net of observing stations in Austria is closer than in any of the other large countries, but the distribution of the stations in the different portions is very unequal.

There are 14 stations of the first order, including the Central Office in Vienna and the independent observatories and institutions, 140 stations of the second order, 194 of the third order, and 18 rain stations.

THE CENTRAL INSTITUTE FOR METEOROLOGY AND TERRESTRIAL MAGNETISM.

This embraces (1) an observatory where meteorological and magnetic observations are made, and (2) a bureau for the administration of the Austrian weather service and the reduction and publication of the observations. The department of Weather Telegraphy has its headquarters in the city proper.

The Central Institute occupies a building erected for it on an elevation called the Hohewarte, 3½ kilometers north of the center of Vienna. The situation is good for meteorological observations generally, though somewhat sheltered on the northwest by hills. The two-story building, with a tower 22 m. high, cov-

ers 615 sq. m., and is situated in a large garden. The building contains apartments for the director and assistants; in the lower story are their offices and a library, a department for storing and verifying instruments, and the magnetic variation instruments for eye observations. The photographic variation instruments are in the basement directly underneath. In the tower are the registers of the anemometers and some astronomical apparatus. Among the trees in the garden are other instruments, and in a wooden pavilion, the magnetic instruments for absolute measurements. The cost of the building was 120,000 florins and of the instruments 40,000 florins.

(1) The normal barometers are a Fortin, constructed by Kappeller, with a tube 10 mm. in diameter, which is read at 7 A. M., 12, 2 and 9 P. M., and a Pistor siphon barometer whose readings are 0.08 mm. lower than the St. Petersburg standard. The normal barograph is the Sprung-Füess, whose error is ±0.04 mm. There is also a Hipp aneroid and a Kreil siphon barograph, which has been in use more than twenty-five years, and serves for interpolation. In this instrument a float in the short leg of the siphon is connected with a lever moving in an arc. Pins on the revolving clock-face press a pencil against a moving paper-covered board. A Theorell meteorograph prints each quarter of an hour the barometer, dry and wet bulb thermometers, wind direction and velocity and the time upon a strip of paper. The heights of the barometer and thermometer are obtained by a style, with battery connections, which is brought into contact with the mercury in the open tubes of these instruments, allowing a current to pass, which stops a revolving type wheel, whose figures are thus printed on the paper. The wind vane and mill each turn a plate which rests on others revolved by the clock. The difference of rotation of the superposed disks is made, in somewhat the same way, to register the direction and velocity of the wind. The large shelter for the thermometers and thermographs is to the north of the building, among trees. It is somewhat similar to the Wild shelter, being inclosed by louvres which are double on the east and west, and by a double sloping roof. The thermometers, which

can be read from the window by a telescope, are 2.50 m. above the ground. Besides the ordinary thermometers, there is the Hipp thermograph and that of Richard, whose indications are reduced for publicaton. There is also a Richard hygrograph. The thermometers belonging to the Theorell meteorograph are placed in the middle of the garden in a similar shelter. Earth thermometers at a depth of 0.37 m., 0.58 m., 0.87 m., 1.31 m. and 1.81 m. are inclosed in wooden cases, the stems of the thermometers covered with a poor conductor, being first inclosed in wooden and then in glass tubes. The three deepest thermometers are read daily, the others tri-daily. Near by are the radiation thermometers, including terrestrial minimum and a maximum black bulb in vacuo.

On the tower is a Campbell-Stokes sunshine recorder. There are three rain gauges, two 1.50 m. above the ground, with a receiving surface of 0.1 sq. m. and 0.05 sq. m., respectively, and one with 0.1 sq. m. surface, level with the ground. The gauge connected with the Osler pluvio-anemograph is 25 m. higher upon the tower. The receiver of another pluviograph containing a float which makes an electric contact for each 1-4 mm. of rain, is placed upon the roof of the pavilion. The rain gauge of Rung (tilting bucket with sine balance) has just been installed. In winter the self-recording gauges are not in operation. A basin 2.25 m. in diameter, filled with water to the depth of 0.3 m., and freely exposed to sun and wind, shows the evaporation by a float in a connecting tube. In this apparatus of Osnaghi, 1 mm. evaporation corresponds to five litres of water. The small atmometer of Wild is in the thermometer shelter. Ozone tests are made with paper whose discoloration is estimated on a scale of 12. The anemograph motors on the tower are a Beckley and an Osler, and the Robinson cups and vane belonging to the Theorell meteorograph. The registers (except the Theorell) are in the room below. The Osler gives direction to 16 points and pressure in pounds per square foot. The Beckley register, built by Adie, has a horizontal cylinder with a metal spiral encircling it which touches a chronograph drum below. The cylinder turns once for 50 miles of wind movement,

and a similar cylinder once for each revolution of the vane. The traces of this instrument are reduced for publication. Besides these instruments there is an apparatus indicating to the public on dials, ouside the building, the height of the barometer and the temperature of the air. For the former element a style is brought into contact with the mercury in the short leg of a siphon barometer each hour, and for the latter the expansion or contraction of rhombs of steel bars connected by zinc tubes is the motor. The relative magnetic measurements are made with the Polar Expedition instruments three times daily. In the cellar is an Adie magnetograph. Absolute magnetic measurements are made with the instruments of Osnaghi twice monthly in an octagon wooden pavilion in the garden.

Another pavilion contains a transit instrument for time determination, and there are a number of other astronomical and magnetic instruments. The eye observations of the standard meteorological and magnetic instruments are made at 7 A. M., 2 and 9 P. M.

(2) The staff of the Central Institute consists of a director (Professor Dr. Hann), three adjuncts (Drs. Kostlivy and Pernter, and Herr Liznar), four assistants and computers, and four servants. The director receives a salary of about 3,500 florins., and the adjuncts about 2,000 florins each, annually. The director is also professor at the University, for which there is no remuneration. Free apartments are provided for him and for two of the adjuncts in the building of the Institute. Postage and telegrams between the Central Institute and the stations are free. The total budget for the maintenance of the Central Institute was, in 1880, about 27,000 florins.

The publications of the Central Institute under Kreil's direction were entitled *Jahrbücher der K. K. Central Anstalt für Meteorologie and Erdmagnetismus*, and were published at the cost of the Academy of Sciences. The first volume includes the observations of 1848 and '49, the eighth and last of the series for the year 1856, appeared in 1861. The observations of the years 1857–'63 were published in a supplement to the *Sitzungsberichte* of the Academy, entitled *Witterungs Uebersichten.*

Since the year 1864 a new series of *Jahrbücher*, in a form somewhat smaller than the first series, has been issued up to the present time. The volume for 1886 (No. 23 of the new series) contains (1) the daily observations at 18 stations according to the international form A; (2) the mean temperatures from 1851 to 1885 or 1880 for 120 stations; (3) monthly and yearly *resumes* of stations of the 1st, 2d and 3d orders; (4) hourly records of automatic apparatus at the Central Institute, embracing:

Pressure in mm.

Temperature in C.°.

Wind direction and velocity.

Resumes of daily periods of pressure, temperature and wind velocity.

Extremes of pressure and temperature.

Frequency and velocity for 16 wind directions.

Duration of sunshine.

Rainfall in $\frac{1}{4}$ mm.

Earth surface temperatures.

Earth temperatures at various depths (five day means).

Minimum temperatures on grass.

Hourly values of certain elements at Eger, Klagenfurt, Gries (Austria), Kremsmünster and Obirgipfel.

(5) Magnetic observations, including:

Absolute and variation measurements.

Hourly values of magnetograph.

Resumes of daily variations of declination, horizontal and vertical intensity.

Results from the indications of magnetograph.

Besides the publication of the data in the *Jahrbücher*, they have been discussed by Jelinek, Hann, Kostlivy, and Pernter in the *Proceedings* of the Academy of Science, in the *Austrian Meteorological Journal*, and elsewhere.

The Stations, their Equipment and Methods of Observation.—The 1st order stations, other than the independent observatories, etc., before mentioned, which report to the Central Institute, have the following outfit of registering instruments:

Austria—Gries: Barograph, thermograph and sunshine recorder.

Klagenfurt: Barograph and sunshine recorder.

Lesina: Barograph, thermograph and anemograph.

Obir: Barograph, thermograph, anemograph and sunshine recorder.

Sonnblick: Barograph, thermograph, hydrograph, anemograph and sunshine recorder.

Eger: Barograph and thermograph.

Lobositz: Thermograph.

Lemberg: [?].

The station on the Hoch Obir (2,046 m.) has been described in Vol. II, No. 11, of the JOURNAL; that on the Sonnblick (3,100 m.), which dates only from 1886, was the subject of a special article in Vol. V, No. 1.

The stations of the 2d order have Kappeller fixed cistern barometers, which require a capacity correction for all readings except those at 760 mm. Their cost is 55 florins. The stations, except those of the 3d order, are supplied with wet and dry bulb thermometers divided to 1–5°, and exposed in a cylindrical zinc screen with a conical roof, open below and to the north, and hung outside a north window. The screen and psychrometer are supplied by Kappeller for 28 florins. New maximum and minimum thermometers of the Six pattern have recently been introduced. The 3d order stations have a thermometer in the above described screen and a rain gauge, the rain stations only the latter.

The rain gauges have a receiving surface of 0.05 sq. m. The receiver is 10 cm. deep, and is joined by a tube to a large collecting vessel, from which the water can be drawn off by a weighted cock into a glass divided to 0.1 mm. This gauge of zinc costs, with the graduate, 12 florins. The receiver is either placed on a white painted box, which encloses the collector and hinders evaporation, or is hung on a post 1 m. above the ground. A new gauge for mountain stations with a funnel receiver and moveable cylindrical collector which can be used alone for snow, has lately been introduced. A few stations only have wind vanes or

atmometers. The instruments are mostly purchased by the observers, but the barometers and thermometers are verified before being distributed. The stations are inspected about once in six years by the staff of the Central Institute.

The hours of observation are generally 7 A. M., 2 and 9 P. M. The instructions to observers are Jelinek's *Anleitung zur Ausführung meteor. Beobachtungen* (revised 1884).

The humidity tables supplied to the observers are those of Wild, corrected by Jelinek. A special correction card is sent out with each closed cistern barometer, in which the corrections for temperature and capacity are combined. The following observations at the 1st and 2d order stations are entered in the monthly table, which is a folio sheet printed on one side of the paper only. At the top of the sheet are: name of station and observer; kind and number of barometer; hours of observation; height above sea-level; height of thermometer and rain gauge above ground. For each day of month: actual readings of barometer and attached thermometer (3 observations); barometer reduced to 0° and daily mean; maximum and minimum thermometer (if used); dry bulb thermometer (3 observations and mean); wet bulb (3 observations); vapor tension in mm. (3 observations and mean); relative humidity in per cent. (3 observations and mean); cloudiness, 0–10 (3 observations and mean); wind direction and force, 0–10 (3 observations); precipitation (kind and amount in 24 hours); remarks (duration of rain, time of thunder-storms, etc.). At the foot of all columns but the first set are the five-day sums, the monthly sums and means; also: number of winds blowing from the eight directions and calms, observed 3 times daily; greatest daily precipitation and date; maximum pressure and date; minimum, do.; maximum temperature and date; minimum, do.

Number of days with precipitation.
do. snow.
do. hail.
do. thunder-storms.
do. fog.
do. storms.

The international symbols are used for the hydrometeors. Pressure, temperature, vapor tension and precipitation are entered to one decimal, the other data in whole numbers. The monthly means are given to one decimal, except the pressure, which is given to two places. Precipitation is measured at 7 or 8 A. M. and entered to the previous day.

The stations of the 1st order have special forms for the hourly tabulation of the automatic registers of pressure, temperature, wind direction and velocity and sunshine.

The observations at the 3rd order and Rain Stations are entered on one side of a sheet. At the top is the name of the station and observer, hours of observation, height above sea-level, height of thermometer and gauge above ground. The columns for each day of the month are thus headed: Temperature (3 observations and daily mean); cloudiness, 0–10 (3 observations and mean); wind direction and force, 0–10 (3 observations); precipitation (kind and amount in 24 hours); remarks. At the foot of the columns are the five-day sums, monthly sums and means of temperature and cloudiness, five-day and monthly sums of precipitation; also: number of winds blowing from eight directions and calms, observed three times daily; greatest precipitation and date, number of days, etc., as in the 1st and 2nd order schedules.

Generally the observers make the necessary calculations and reductions in the monthly tables and send them to the Central Office, where they are checked.

Weather Telegraphy.—The service was commenced in 1865, but up to 1872 the data received were from Austro-Hungary only. The issue of the autographic *Bulletin* dates from 1873, and in its present form from 1877. The headquarters of the department of Weather Telegraphy since 1881 have been at No. 2 Universitäts Platz, under the management of Herr Warcka who has an assistant and a telegraphist. Free telegraphic reports are allowed, and the budget from the Minister of Commerce was, in 1880, 1,300 florins.

The telegraphic material includes morning dispatches from 29 domestic and 36 foreign stations, received in exchange with

9 other Central Institutes, and the 2 and 9 P. M. reports from a few stations. From these reports in the international cipher code the *Telegraphic Weather Bulletin* is prepared about 3 P. M. and issued between 5 and 6 P. M. It is a folio sheet with the base map and stations printed in blue and the current data lithographed in black. On one page are the following reports from all the stations for 7 A. M.: Pressure in mm., reduced to sea-level; temperature in C.°; wind direction and force (1–12); cloudiness; precipitation; maximum and minimum temperatures. Special observations for 7 A. M. and 2 P. M. of the preceding day are given for the Sonnblick (3,100 m.) and its base station (1,600 m.), and at 2 P. M. for two other stations. The pressure at the four mountain stations, Sonnblick, St. Gotthard, Sentis and Obir, is reduced to the same level of 2,500 m. At the bottom of the page are remarks, and on the opposite page is a map of Europe for 7 A. M., with isobars for each 5 mm. The temperature is expressed in degrees for each station, the wind direction and force and the weather by symbols. A general review of the weather conditions and general predictions of wind, weather and temperature complete the *Bulletin*, which costs 30 florins a year to subscribers, and has a circulation of about 200.

These weather reports are printed in abstract by several Vienna and provincial newspapers. No storm warnings are issued, but since 1878 an agricultural weather service exists in summer. For this purpose the general weather conditions and the predictions for the next day are telegraphed by a code between 2 and 3 P. M. to some 15 local centres, where the predictions are translated, modified to suit local conditions, and forwarded to subscribers, of which there were, in 1880, 80 who paid 10 florins a month, the Government allowing 50 per cent. reduction on these dispatches. The percentage of success of these forecasts for all elements and districts is about 85.

THE INDEPENDENT OBSERVATORIES, ETC.

Cracow.—This well situated astronomical observatory possessed in 1879 an aneroid barograph and thermograph of Hipp, a printing wind-vane of Osnaghi, an electric registering

anemometer and some magnetic apparatus. Tri-daily observations at 7, 2 and 9 o'clock are made and published monthly by the director, Professor Dr. Karlinski. This observatory superintendents the system of 2d and 3d order stations, established by the Cracow Academy of Sciences in Galicia, which do not stand in direct relation with the Central Office in Vienna.

Kremsmünster.—This ancient abbey is situated south-east of Wels, a station on the line between Linz and Salzburg. The observatory consists of an eight-story tower on a plateau, dominated in part by higher hills. Meteorological observations here date from the last century. Those from 1763 to 1851 have been reduced and published in the *Jahrbuch der K. K. Central Anstalt* for 1854; later observations in the *Jahresberichten des Museum Francisco-Carolinum* in Linz, and in the *Astronomischen Nachrichten.* Discussions of the data have been made by former directors. Since 1878 the observatory has possessed registering apparatus whose indications are published in the *Jahrbuch.* These instruments comprise a Kreil barograph, a thermograph of Hipp, an Osnaghi printing windvane, and electric registering anemometer and a sunshine recorder. Since 1841 tri-daily observations of magnetic variation have been made, together with occasional absolute measurements, and these observations, up to 1851, have been reduced and published by A. Reslhuber. The present director of the observatory is Father Colman Wagner.

Prague.—The first meteorological observations at the Jesuit Collegium Clementium date from 1752. Their scope was greatly extended in 1839 by Kreil, who published the first annual report. The observatory is in the midst of an aggregation of buildings and is wholly unsuited to astronomical work, so that more attention is now devoted to meteorological and magnetic observations, though the exposure of the thermometers and rain gauges is not good. Direct barometer readings are made five times daily, and besides there is a Kreil barograph and one of Hipp. The thermometers are read at the same hours as the barometer, while a Hipp thermograph permits the determination of the temperature at the even hours. The rain

gauges and atmometer are on the roof. One of the former belongs to an Osler pluvio-anemograph. There is also a Beckley anemograph and the normal Robinson anemometer of Kraft. Cloud and ozone observations are made five times daily. A noteworthy discussion of the hourly values of the meteorological observations was published in 1850 by Dr. Jelinek. Relative magnetic measurements are made at the observatory four times a day, the absolute measurements being made outside the city. The meteorological and magnetic observations are published by the observatory in an annual volume. The observatory belongs to the University, and the director is paid as one of the professors.

Pola.—The Hydrographic Office of the Austro-Hungarian navy in Pola embraces four departments, viz., an astronomical observatory, an instrument depot, chart depot and library. The observatory, whose main purpose is to rate chronometers, has a meteorological-magnetic department. The meteorological observatory, since 1871, has been situated upon a hill with a free outlook, in the south part of the old town. Pola is really the chief station of the Adriatic Sea, neither Fiume, Trieste nor Venice being so well equipped. The outfit of registering apparatus in 1882 was this:

A Wild balance barograph by Hasler and Escher;

An electric aneroid barograph of Hipp;

An electric thermograph (dry and wet bulbs), by Hasler and Escher;

An electric thermograph of Hipp;

Two electric registering anemometers;

A registering wind vane of Kreil;

A registering rain gauge of Kreil; and

A Campbell-Stokes sunshine recorder.

Besides the ordinary instruments there are solar and terrestrial radiation thermometers, two atmometers, rain gauges at two heights, a tide gauge and two seismometers. Direct tri-daily meteorological observations are made synchronously with those of the Central Office, together with others which, serving as standards for the measurements of the curves of the self-

recording instruments, are checked in the daytime, while the double set of self-recording instruments control each other. Jelinek's tables are used for the reduction of the observations which are published by the Hydrographic Office monthly and annually in the *Mittheilungen aus dem Gebiete des Seewesens.* Since 1876, hourly values have been published.

There are a number of magnetic instruments, and observations of the compass are made for the immediate benefit of navigators, together with daily tide measurements. Daily weather telegrams are received from Vienna and Trieste, and bulletined, together with the local observations, but storm warnings are no longer issued. The Hydrographic Office is under the direction of Dr. R. Müller, and the observatory is conducted by naval officers.

Trieste.—The observations at the Nautical and Commercial Academy were commenced in 1841, but until 1860 the station was of the 2d order. Since then it has had a barograph, thermograph and anemograph. Five direct observations are made daily, and published monthly by the city Statistical Bureau. The observations from 1841 to 1873 have been discussed in the *Jahrbuch* by Osnaghi. In charge of the observatory is a mareograph and some seismometric apparatus. For some years a daily weather chart was issued, and as early as 1866 storm warnings were attempted. The astronomical-meteorological observatory is managed by director Osnaghi, who issues an annual Report in Italian, containing hourly readings at Trieste and the tri-daily observations at Pola and Lesina and at other Adriatic stations.

The Rainfall Observations in Bohemia.—The importance of the relation of rainfall to forests in Bohemia caused an extensive investigation of the rainfall to be undertaken. In 1880 the stations numbered about 1,000, and covered the country more densely than those in Great Britain.

The system of rainfall observation is carried on by the meteorological section of the Hydrometrical Commission of the Kingdom of Bohemia and by the Bohemian Forest Association. The stations of the former organization number about

300, and their records have been discussed by Prof. Studnicka in the *Proceedings of the Bohemian Scientific Society* of Prague. The Forest Association, in 1880, had about 700 stations. The growth of the system is due to the director, Dr. von Purkyné, and to the liberality of some large landed proprietors. The observers are mostly foresters, who record phenological and rainfall observations for their employers. All the rain gauges are placed 1 m. above the ground and are read at 8 A. M. On the first of the month the data of the preceding month are sent on post-cards to the Forest School in Weisswasser. The observations have been published in detail, and the cost of the service amounts to about 3,000 florins a year, exclusive of the first cost of the rain-gauges which aggregated 8,000 florins. After the death of Dr. von Purkyne all rainfall station have been centralized by Professor Studnicka, who recently published a résumé entitled *Hyetographie des Königreichs Böhmen.*

THE GREAT STORM OFF THE ATLANTIC COAST OF THE UNITED STATES, MARCH 11-14.*

The speaker commenced by referring briefly to the difficulties and delays that necessarily attend the collection of data by which to study the character and progress of a great ocean storm, illustrated by the fact that a ship which recently arrived at New York from Calcutta supplied very valuable data regarding one of the great hurricanes of August last, from a region to the westward of the Cape Verde Islands, where data were specially needed.

Four large colored charts were used to illustrate the meteorological conditions over the area charted (lat. 25° to 50° N., long. 50° to 85° W.) at 7 A. M., 75th meridian time, March 11th, 12th, 13th and 14th, respectively. These charts contained isobars for each tenth of an inch, reduced pressure, and isotherms for each 10° Fahrenheit, temperatures above freezing, in a tint of vary-

*Abstract of a paper read before the National Geographic Society, Washington, D. C., April 27th, by Ensign Everett Hayden, U. S. N., in charge of the Division of Marine Meteorology, U. S. Hydrographic Office.

ing intensity of red, and below freezing, of blue. A large track-chart, with vessels' positions and tracks, enabled the audience more clearly to follow the discussion and the storm reports which were quoted. A barometer diagram illustrated the fluctuations of the barometer at six land stations and on board six vessels, selected with special reference to the completeness of their data and their position relative to the storm. Diagrams were prepared, also, to show the varying height of the barometer along north-and-south sections, selected to emphasize the fact that the special feature of the storm was its trough-like form, the isobars about the area of low barometer being elliptical in shape, along a north-and-south line, and moving eastward between two ridges of high barometer.

The synchronous weather charts were taken up and discussed successively. The first, that for 7 A. M., March 11th, showed a trough of low barometer reaching from the gulf far northward, past the eastern shore of Lake Huron, toward the southern limits of Hudson Bay. Off the coast, a ridge of high barometer stretched down from the Gulf of St. Lawrence toward Santo Domingo, passing about midway between the Bermudas and Cape Hatteras. To the westward, another ridge of high barometer extended from Dakota to below the Rio Grande. Along the coast the prevailing winds were, therefore, easterly and southeasterly, the warm moist air drawn up from far down within the tropics causing a warm wave, with generally cloudy weather and rain. In rear of the line of low barometer a cold northwesterly wind was blowing, carrying a cold wave far down into the gulf, with frosts as far south as Louisiana and Mississippi, and cool northerly winds clear down to Vera Cruz.

Before considering the next chart, time was taken for a description of the meteorological conditions off the coast, awaiting the advance of this long line of cold northwesterly gales which was moving eastward at the rate of about 600 miles a day. Attention was called to the importance of considering, in this connection, the vitally important influence of the great warm ocean current, known as the Gulf stream, in increasing the energy of storms when they reach the coast. By way of

more vividly illustrating the energy of action developed when cold winds blow over it, mention was made of the many water-spouts reported off the coast the last few months, and a few of these reports were quoted. It was shown, also, that the surface temperature in the axis of the Gulf stream off Hatteras was as high as 76°, while that of the cold inshore current was fully 30° lower.

The storm was then followed as it approached the coast, its energy increasing every hour and the barometric depression deepening. At 3 P. M., one center, with pressure as low as 29.7, had just passed the coast south of Hatteras, while another, with pressure quite as low, or lower, was central over the province of Ontario. Although the general trough-like form of the storm remained, as clearly indicated by reports from vessels all along the coast, yet another secondary storm center, and one of very great energy, formed off shore north of Hatteras, as soon as the line had passed the coast. It was this center, in violence fully equal to a tropical hurricane and rendered still more dangerous by the freezing weather and blinding snow, which raged with such fury off Sandy Hook and Block Island for two days,—days likely to be long memorable along the coast. Its long continuance was probably due to the retardation of the center of the line, in its eastward motion, by the area of high barometer about Newfoundland, so that this storm center delayed between Block Island and Nantucket, while the northern and southern flanks of the line swung around to the eastward, the advance of the lower one gradually cutting off the supply of warm moist ocean air rushing up from lower latitudes into contact with the cold northwesterly gale sweeping down from off the coast between Hatteras and Nantucket.

So far as the ocean is concerned, the night of the 11th-12th saw the great storm at its maximum, and its great extent and terrific violence make it one of the most severe ever experienced off our coast. Only a few corrected barometric readings were lower than 29.00, and the lowest pressure was probably not lower than 28.9, although lower readings were observed a few days later, off the Grand banks.

The chart for 7 A. M., March 12th, showed the line, or *trough*, with isobars closely crowded together southward of Block Island, but still of a general elliptical shape, the lower portion of the line swinging eastward toward Bermuda, and carrying with it violent squalls of snow and hail far below the 35th parallel. The high land of Cuba and Santo Domingo prevented its effect from reaching the Caribbean Sea, although it was distinctly noticed by a vessel south of Cape Maysi, in the Windward Channel. The isotherm 32° reached from central Georgia to the coast below Norfolk, and thence out into the Atlantic to a point about 100 miles south of Block Island. Farther north, it ran inshore of Cape Cod, explaining the fact that so little snow, comparatively, fell in Rhode Island and southeastern Massachusetts.

By next morning the storm was beginning to decrease in severity, and the chart shows that westerly winds and low temperatures had spread over a wide tract of ocean below the 40th parallel, while over the ocean north of that parallel the prevailing winds were easterly. The lower storm center was now in about lat. 40. N., long. 59, W., with a pressure of 29.30, and the other a little distance south of a line from Nantucket to Block Island, barometer 29.00, the isobars extending in a general easterly and westerly direction. The delay of the storm off the coast, and its rapid increase of energy, had been shown in the most marked manner by the fluctuations of barometers, both at land stations and aboard vessels, and the barometer diagram was referred to by way of illustration.

At 7 A. M., March 14th, the storm off Block Island had almost died away, with light variable winds and occasional snow squalls; the other center was about 200 miles southeast from Sable Island. The great wave of low barometer had overspread the entire western portion of the North Atlantic, with unsettled, squally weather from Labrador to the Windward Islands. The area of high pressure in advance had moved eastward, to be felt over the British Isles from the 17th to the 21st of the month, and after it a rapid fall of the barometer. The isotherm of 32° reached from the southern coast of North Carolina well

off-shore, thence northward to the coast of Maine, and from central Maine eastward across Cape Breton Island and southern Newfoundland. From the southeastern to the northwestern portion of the chart, the shades of color showed a difference of temperature of more than 80° (from above 70° to below — 10°), but such great differences of temperature and pressure could not last long, and the normal conditions were gradually restored.

The paper will probably appear in full in the Proceedings of the National Geographic Society, and will be published, with copious extracts from vessels' meteorological journals and storm reports, by the Hydrographic Office, for circulation amongst the maritime community.

THE TRANS-MISSISSIPPI RAINFALL PROBLEM RESTATED.

By Geo. E. Curtis.*

To demonstrate satisfactorily the occurrence of changes in climate has come to be considered one of the difficult problems of meteorology. The evidence of a climatic change may be based either upon general records of the character of the weather for different periods, or, when available, upon instrumental observations.

It would seem that the latter data would easily furnish the means for giving a decisive answer to such questions; yet it has been found that, owing to the changes in observers, instruments, exposures, and methods of observing, much uncertainty inheres in the results.

For example, the older European temperature observations were made with rudely constructed thermometers, whose proper comparison with modern instruments is a matter of much difficulty.

A few comparisons of these old observations with present data have been made, the general result of which has tended to indicate the permanence of climate. Among these is a recent study of the records of the Florentine thermometers, which carry us

* Read before the New England Meteorological Society, April 17, 1888.

back to the beginning of modern instrumental observations—the author concluding that the present temperature of Florence had not sensibly changed for 200 years.

In the United States rainfall records extend back at Charleston to 1738, and temperature observations running back into the last century are available for a number of eastern places.

Independently of conclusions resulting from a study of these instrumental observations, wide-spread beliefs in the occurrence of recent climate changes have become prevalent in this country, and are firmly held by large numbers of the people. Of such generally accepted beliefs is one prevalent in Connecticut, and perhaps in neighboring States, that the Spring is much later than it was a half century ago. The older farmers relate that when they were boys it was customary to complete a certain stage of farming operations before General Training day, or to begin the planting of a certain crop on the day following that notable holiday; whereas, now, the same operations are delayed by the prolonged winter to a much later date. A similar popular belief in a climatic change, current throughout the middle west, is that their rainfall is increasing, and the cause of this increase is attributed to the building of railroads and the extension of cultivation. The wide-spread prevalence of this general impression is of itself an interesting and important fact, and carries a weight that claims the most respectful attention. For, if founded in accurate, though not instrumental, observation, it will have a *raison d'etre* that will go far to establish its truth. The discussion of the grounds for this belief is the subject of the present paper.

As already stated, the origin of the idea is independent of the results of strictly meteorological rainfall records. If proven true, therefore, will it not suggest that the long continued observations and experience of intelligent farmers may be a keener and surer discoverer of climatic changes than the meteorologist with his tables or data? My own inquiries, however, have shown that, in general, the current belief in an increase of rainfall does not rest as much on observation as on a fallacious argument. Based upon the reports of early explorers, all the country west

of the Missouri was believed thirty years ago, to be a "Great American Desert," in which agriculture would always be impossible because of the insufficiency of rain.

A few years later Eastern Kansas was settled, and yet, for the first ten years thereafter, few believed that the frontier of settlement could ever be extended west of Topeka. The stream of immigration, however, has still pushed westward and, as yet, no absolute limit has been reached. Still holding to the essential truth of their previous assumption, the older settlers naturally explain this westward advance of agriculture as having been rendered possible by an increase of rainfall, gradually produced by the tillage of the soil and the growing of trees. But the argument is fallacious because of its defective promise. The possibilities of the country for agriculture were underestimated by reason of the lack of the proper experience for forming a correct opinion.

Before the breaking of the soil, the surface of the plain, trampled upon for innumerable ages by immense herds of buffaloes, baked hard by the sun, and beaten by the rain, shed water 'like a shingled roof.' The plow over ten million acres of land has broken through this water shedding roof, the rainfall is absorbed into the soil, and a reservoir of moisture thereby provided in the sub-soil for vegetation to draw upon in times of drought. As an evidence of this result, the streams which formerly fluctuated from dry beds to destructive torrents have a much more even flow. As another result, too, the statement is made, and I see no reason to doubt its truth, that with this increased moisture of the soil, and growth of vegetation, there has come an increased humidity of the atmosphere, and a more general diffusion of moisture.

Cultivation, growth of grasses, tree planting, prevention of destructive prairie fires—these are the agencies that have wrought a change in the conditions of agriculture in Kansas. All can have been effected without an increase of rainfall of a single inch. The general impression of such increase is originally founded, I believe, in a mistaken argument, and unless supplemented by more accurate observation, and supported by

more careful reasoning, it cannot be considered to have an established value.

But abundant discussion of the question in scientific, agricultural, statistical, and popular magazines and journals has not been lacking. During the past year, especially, there has been an active revival of interest in the question, and the subject has been discussed by a galaxy of eminet writers. Upon the negative side of the question, relatively little has been written, and for the reason, I suppose, that the burden of proof rests with those who believe in the increased rainfall to establish the proof.

Ex-Senator Dorsey in the *North American Review* says, "Nothing is more idle than the talk that can be heard on all sides respecting the rainfall increasing within what is known as the arid region. The rainfall has been accurately recorded as far back as 1847 at Ft. Riley, Kansas; Ft. Bent, Colorado; Santa Fe, New Mexico; Ft. Bridger, Wyoming, and Salt Lake City. These records show that the rainfall from 1850 to 1860 was two inches more than from 1870 to 1880. There has been no increase whatever in the past forty years. I challenge those who persist in claiming that what is now known as the arid region will sooner or later become productive by the natural rainfall to show me a single instance anywhere on the surface of the earth where such a result has been obtained. There has been no climatic change on this or any other continent."

These positive statements are made by Ex-Senator Dorsey in advocacy of a new system of public land laws, and are not accompanied by the data upon which they appear to be based. As a contribution to the meteorological question, this failure to present the data is a serious one, for those who have reached an opposite conclusion from a study of the observations, will hardly be disposed to accept his unsupported statements. A similar conclusion, together with the data on which it is based, has been presented by the eminent geographer, Mr. Gannett, in a recent article in *Science.* He takes the observations from twenty-six stations in Kansas, Nebraska and adjacent western territories; divides the series from each station into two parts; takes the

sum of each part, and, upon finding no sensible difference between the two, concludes that the rainfall observations indicate no increase of rainfall. This method is pursued by Mr. Gannett is decidedly faulty. One-half of the stations have short series of from three to twelve years in length, while the remaining are from twelve to twenty-eight years. If, now, an increase has occurred, it must be discovered by dividing the observations so that each portion shall cover entirely separate periods. It is difficult to see how the mixture given by Mr. Gannett can possibly throw any light on the subject.

The remaining writers to those arguments I shall refer in this *resumé* support the popular belief. Mr. Charles Francis Adams in the New York *Nation*, and General Greely in *Science* are each disposed to believe that the rainfall has increased, but do not give any substantial grounds for their opinion. General Morrow, in an address on October 5th, 1887, at the Sidney fair, advocated the popular view of an increase of rainfall due to cultivation, with the following argument: "I have always thought there was an abundance of moisture in the clouds of the interior section of the country, but that conditions favorable to its precipitation in the form of rain and dew were wanting. The earth and the sky are reciprocal in their relations. They give to and take from each other. A parched desert having nothing to give in return receives no moisture from the passing clouds." This is an attractive poetical view, but it can be considered valuable to meteorology only after it has been shown to have a rational physical foundation.

The really valuable contribution of the year, in my opinion, is that by Prof. Harrington in the AMERICAN METEOROLOGICAL JOURNAL for December, 1887. A careful comparison of the rainfall charts based on the recent Signal Service observations with the charts contained in Blodgett's Climatology of the United States, shows an unmistakable westward advance of the isohyetal lines over the western plains. By this method, all of the data up to 1855–56, consisting mainly of the records at the military posts, is utilized for the first period, and the valuable signal service records for twelve years from 1871 to 1883 for the

second period. The certainty of the conclusion seems, therefore, to depend mainly on the degree of accuracy with which the meagre data available in 1855 truly represents the average rainfall of so great a district, and the resulting degree of precision with which this scanty material can furnish the isohyetal lines.

The graphical method has the advantage of being able to make use of a large amount of scrappy data which a numerical discussion would find it difficult or perhaps impossible to utilize, but it furnishes little means of determinating how much confidence its results are entitled to.

Prof. Harrington says it is perhaps to the advantage of this comparison that the two charts are constructed from "entirely different series of observations." But it seems to me that this is one of its most fatal defects. That a series of observations to be used for comparative purposes should, if possible, be continuous and uniform I have always supposed to be one of the first axioms of meteorology. When, then, I find that the second chart is constructed from a new seat of observations in very different places, by observers, working under different rules, and with different kinds of gauges from those in use at the old military posts previous to 1855, it seems to me that there is a discontinuity that must be proved to have no injurious effect in the comparison before I can fully accept its results. Between the records of his gauges in the city and on the University hill at Lawrence, Kansas, Prof. Snow finds a permanent and nearly uniform difference. If for one portion of his series he used one gauge, and for another portion the other guage, what would his record be wrrth? He could obtain a material increase or decrease of rainfall at will, according as he used one or the other for his earlier series.

Owing to the great irregularity in the distribution of rain, especially in hilly countries, it seems to me not only very possible, but in fact very certain, that any given small number of gauges will collect a rainfall that will have, on the average, a certain definite departure from the true mean, which latter can be obtained only by an indefinitely large number of gauges. A

certain other set of gauges will have their peculiar departure or error. Now, if the error of the first set be negative, it is an even chance that the error of the second set will be positive, and, in this case, the difference between the two sets of gauges will be the sum of the *errors* of each.

An illustration of this source of error is found in General Greely's statement that he believes that the whole system of Union Pacific observations, because of their peculiar topographical location, have given results less than the true average of the surrounding district.

Another source of disparity between the army fort and the Signal Service records, and one more likely to be systematic, lies in the rules and methods of observation, and in the intelligence and spirit of the observers prevailing in the two cases.

At the forts the observations, made by the hospital stewards, or by a more subordinate soldier, are generally considered a most irksome duty.

The records often show that the measurement of the precipitation in showers and light rains has been neglected as too small to be of importance; the proper method of measuring snow was often but little understood and the resulting records are frequently open to the widest range of interpretation. For these reasons a conclusion of increased rainfall based on the difference between these two series of observations, seems subject to considerable uncertainty.

The graphical method without the accompanying data presents only an apparently conclusive result that gives opportunity for probing or close inspection. The numerical and analytical discussion of the data, on the other hand, ought to bring out whatever truth the observations contain, while it has the great advantage of enabling us to form an estimate of its value. To do this, however, much scrappy material which is in itself of value must be rejected.

Numerous writers have discussed portions of the data. In 1884 Professor Snow, after reviewing the Kansas observations, concluded that the rainfall of Kansas has been increasing, and endorsed the general view that settlement and cultivation has

been its cause. Since Kansas is the very center of the district under discussion, I think this society will be interested to examine the observations from this State that bear upon the question.* These consist of records at four stations in Eastern Kansas:

Leavenworth......................50 years.
Manhattan.........................30 years.
Ft. Riley...........................30 years.
Lawrence..........................20 years.

KANSAS PRECIPITATION TABLES.

Fort Leavenworth and Leavenworth City. Lat. Long.

Period.	No. of years.	Amount.	Observers.
1837-1846	10	30.4 ± 1.9	
1847-1856	10	32.3 ± 1.7	Army Surgeons.
1857-1865	9	33.7 ± 3.2	Signal Service.
1867-1876	10	36.0 ± 1.3	
1877-1886	10	38.3 ± 1.9	

Fort Riley. Lat. Long.

Period.	No. of years.	Amount.	Observers.
1854-1863	10	23.7 ± 1.2	
1864-1874	11	25.0 ± 1.2	Army Surgeons.
1875-1887	13	25.7 ± 1.2	

Manhattan. Lat. Long.

Period.	No. of years.	Amount.	Observers.
1858-1867	9	†30.7 ± 1.5	
1868-1877	10	31.2 ± 1.8	State Agricultural College.
1878-1887	10	31.5 ± 1.0	

Lawrence. Lat. Long.

Period.	No. of years.	Amount.	Observers.
1868-1879	10	34.9 ± 1.1	Prof. F. H. Snow.
1878-1887	10	35.2 ± 1.4	

The above table gives these data in ten year means. The selection of ten years as the period for taking the means has

* In the completion of these tables I am indebted for recent data to Professor J. T. Lovewell, Director of the Kansas Weather Service.

† The records from 1858 to 1868 are very incomplete, and the annual totals are obtained by interpolation. The mean 30.7 is based on the annual totals given in the Smithsonian Tables: the record as constructed by some makes this mean 31.3.

been made after finding that means for any shorter number of years are too uncertain and variable to be of value in the present discussion. But after adopting ten years on the shortest period from which valuable averages can be obtained, the degree of confidence that can be placed in these averages still needs in some way to be ascertained. Although fully recognizing that the principles of least squares pertain strictly to accidental errors of measurement, and that their extension to the discussion of variable phenomena has not been proven to be legitimate, I nevertheless venture to follow the practice of the leading meteorologists in using the methods of least squares as giving the best practical proximation to the desired result.

I have, therefore, computed by the formula for *probable error* what may be called the *probable uncertainty* of each mean. The meaning to be attached to the result 34.9 in. ± 1.1 is, therefore, that it is an even chance that 34.9 differs from the mean of a very long series by more (or less) than 1.1 inches.

This table shows that the probable uncertainty of any ten-year mean at these stations ranges from one to two inches, and on the average is 1.4 or 1.5 inches. Manifestly, therefore, any variation that is to indicate a real climatic rather than a fluctuational increase of rainfall should be somewhat larger than this probable uncertainty.

In the records from Manhattan, and Lawrence, the means of the second half of the series are slightly larger than the means of the first half, but the increase is less than the probable uncertainties of these means, and so furnishes no indication that the increase has any climatic significance.

The Lawrence series consists of Prof. Snow's magnificent record for the past twenty years, which is so complete and accurate that its trust-worthiness is unequalled by any other Kansas record. The means of the two halves of this series are sensibly identical. But in 1884, when the series was sixteen years in length, and each half contained eight years, by reason of a curious bunching of years of copious and scanty rainfall, the mean of the latter half was considerably greater than that of the first half, and Professor Snow was thereby led to believe

that his observations supported and strengthened the view of a permanent climatic increase of rainfall. It now seems apparent, however, that that conclusion was premature, owing, either to there being an insufficient number of years to eliminate the accidental fluctuations, or if there be a seven-year period in the rainfall, as Professor Snow now believes, to the fact that the two halves of his series did not symmetrically cover such periods.

The fifty years record at Leavenworth shows an unmistakable increase in the recorded precipitation, beginning with the fourth decade in 1867, and continuing to the present time. Thirty years ago no considerable portion of Kansas soil had been turned by the white man's plow. The Ft. Leavenworth record carries us back, therefore, to the pre-agricultural days of Kansas, and shows without question—not that cultivation has increased the rainfall recorded at Ft. Leavenworth was, on the average, seven inches less than is now collected by the Signal Service observer located in Leavenworth city.

Expressed in this form, we see that the discontinuity of the record which took place in the fourth decade makes a serious defect in the comparison. It is the same defect already mentioned as inherent in Professor Harrington's graphical results. Leavenworth is situated in a hilly country where a material difference of precipitation within comparatively short distances is likely to occur. If it can be shown that the difference in the location of the gauge or in methods of measuring cannot account for the large observed increase, the conclusion that the recorded excess in the later years is due to cultivation and settlement is not yet a necessary one.

When I turn to the rainfall records of Providence, Washington and other eastern cities, I find an increase in the recorded rainfall no less striking than that at Ft. Leavenworth or other western stations.

Has cultivation of the soil, tree planting, railroad building and settlement been the cause of the six inches increase of rainfall at Philadelphia, and of the eight inches increase at Providence and New Bedford? And if not in these places, why is

it so certain that they have been the cause of the same phenomenon in Kansas? If settlement and cultivation can measurably increase the rainfall, how is it to be brought about? What is the *rationale* of the process? Who has shown that the assigned cause is *adequate* to produce the effect that is claimed for us? These important questions, an answer to which would furnish a rational ground for the general opinion, are seldom squarely faced.

PRECIPITATION ON THE ATLANTIC COAST.

Providence, R. I.

Period.	No. of Years.	Average Annual Amount.
1832–1839	8	36.3
1840–1849	10	40.2
1850–1859	10	45.2
1860–1869	10	46.5
1870–1879	10	50.0 (47.95)*
1880–1887	8	50.3 (46.88)*

Period.	No. of Years.	New Bedford.	Philadelphia.
1835–1844	10	30.3	42.0
1845–1854	10	40.8	42.6
1855–1864	10	40.8	45.3
1865–1874	10	47.6	48.1

Turning, therefore, from the inconclusive discussion of the rainfall records, I will conclude this presentation of the subject by quoting a portion of a most interesting and suggestive paper read by Mr. H. R. Hilton before the Kansas Academy of Sciences, in 1880, in which he lays hold of these important question.

THE RAINFALL IN ITS RELATIONS TO KANSAS FARMING.

"The source of our water supply is mainly in the Gulf of Mexico. This supply is transported hither by means of the great aerial currents that flow northward from the gulf with so little variation during the summer months. The same influence

* The figures enclosed in brackets are obtained from those in the first column by correcting for an error in the Signal Service gauge known to be of "at least 10 per cent,"

that brings to the Mississippi valley states, parallel with Kansas, their supply of moisture, brings it to Kansas. Our rainfall is less, simply because we offer less favorable conditions for precipitation. Simply these conditions, and our rainfall is measably comparable with other states. Where the rainfall of Kansas is deficient, it is more a lack of necessary conditions of soil, vegetation and local evaporation than a lack of humidity in the aerial currents passing over. The latter are rarely wanting in moisture during the summer months. The conditions necessary to wring this moisture from the atmosphere are conspicuously absent over a large area of Kansas, and these are: deeply-plowed and well-cultivated fields, growing crops, larger area of trees, ponds of water, and ranker vegetation of all kinds more generally distributed.

A comparison of the climate of the eastern half of Kansas, before and since it has been brought under man's civilizing influence, affords strong proof of the climatal changes brought about by settlement. What Kansas is to-day west of the 99th meridian, all of Kansas lying west of Topeka was twenty-five years ago. Vegetation was scant, and prairie fires burned off the meagre amount almost annually. Hot winds winds were a consequence of this exposed heat-radiating surface. The principal rain supply of the summer months was through the medium of thunder storms of great severity. Precipitation took place at a high elevation, and was very rapid. Gentle showers and general rains, such as we are now frequently favored with, were then very rare. *Even if no more rain falls* on the earth now than in the early days of the state's history, *it is better distributed throughout the season*, and thunder storms are not marked with their formed severity. The tall, blue-stem grasses, that could not withstand the dry, arid climate of the plains, now follow in the wake of the settlements, and takes possession of the soil, and I believe their influence has been greater than all other causes combined, because by covering the major portion of the country with a heavy coating, that greatly reduced radiation, they removed one of the most stubborn agencies that the pioneer had to contend with.

In the pre-civilized days of Kansas, when vegetation was very sparse, the sun's rays poured down upon the unprotected surface, which, owing to its hardness, absorbed but a small portion, and instead, threw it off into the surrounding atmosphere. A local stratum of hot, dry air was thus formed in contact with the earth's surface. Being of greater density than the moist currents above, its motion became lateral instead of upward; and on account of this lateral motion, the air, in passing over a large area of heated surface, became intensely heated. With the increased temperature came increased velocity, and hence the hot winds so prevalent on the plains many years ago, and now occasionally experienced on and beyond our frontier of settlements.

My theory is that this stratum of hot, dry air, next the earth's surface, insulates the ground from the moist aerial currents passing over. When an electric discharge from the clouds to the earth takes place, the resistance of the dry air makes its severity and destructiveness many times greater than would be the case were a good conductor provided. Atmospheric electricity is now believed by many to be a result and not a cause of precipitation. I believe it, however, to be an important factor. When an electric discharge takes place between clouds and earth it is generally followed by the condensation of vapor and rainfall.

If I am correct in my theory of the stratification of the atmosphere, it is obvious that in order to change the climate, we must remove the insulating stratum of dry air and bring the earth and the moist currents more nearly in contact with each other. The tendency of thunder storms to follow streams and timber belts may be attributed, I think, to the greater amount of humid air that is there ascending. Anything that will aid in increasing evaporation will aid in establishing better communication between the clouds and the earth, and insure a greater frequency of local showers during the summer season. To increase our rainfall, then, we must do two things: Reduce radiation and increase evaporation. The local evaporation does not, as many think, provide the moisture for additional rain, for at

best it can yield only a small amount; but it is valuable to us because it furnishes the conditions necessary to wring from the atmosphere the moisture that is there in store."

I have quoted so large a part of Mr. Hilton's paper, not as endorsing his theory, but because he has squarely met the questions as to *how* cultivation and settlement can increase rainfall, and has stated his solution with so much completeness and clearness that the merits of his theory can be discussed from a meteorological and physical standpoint.

If this re-statement of the trans-Mississippi rainfall problem has led to no conclusion, it is because the present writer has no theory to advocate, but has endeavored simply to present the various arguments on the subject, with such comments as they seem to merit, in order that this honored society by its valuable discussion may largely contribute to the final solution of these vexed problems of climatic change. GEO. E. CURTIS.

TOPEKA, KANSAS, April 10th, 1888.

TEMPERATURE IN AREAS OF LOW AND HIGH PRESSURE.

BY A. WOEIKOF.

Mr. Allen Hazen again states his views on this subject (JOURNAL, March, 1888, p. 527) referring to and disputing the opinions lately expressed by Hann* and Dechevrens.†

The principal point of Mr. Hazen seems to be that the law that during the passage of areas of "high" (anticyclones) the temperatures on high mountains are high in winter is not applicable to Mt. Washington, and thus no law at all.

Now, it seems to me there is a great deal of misunderstanding on this question. Dr. Hann cites the following figures from the observations of Mt. Washington (in all 45 of the cold months, November to March, in the ten years 1875–84):

MORNING OBSERVATIONS.

(Calculated by Mr. Dechevrens.)

Mean pressure mm	612	608	604	600	596	592	588	584	580	574
Mean temperature C°	–4.7	–6.9	–8.9	–10.6	–12.2	–14.5	–15.9	–19.3	–18.2	–23.3
Number of Cases	26	92	195	261	317	209	152	70	28	15

* Meteor. Zeitschr., 1888, p. 7.
† L'inclinaisons des vents.

Does Mr. Hazen consider these figures to be exact or not? If he does, they show very clearly that on Mt. Washington, in winter, temperature is lower with low pressure and higher with high. The only exception disappears if we except the figures based on less than 50 cases. Thus we have —6.9 with a mean pressure of 608, and —19.3 with a pressure of 584, or mean lowering of the temperature of 0.52 C° for the lowering of pressure by 1 mm. The changes are seen to be even more regular and great than for European peaks, on Mt. Washington, and especially on Pike's Peak. I give the figures for the extreme pressures, calculated by Dechevrens.

	Mt. Washington. 1914 m.	(*) Pike's Peak. 4330 m.	(*) Pic du Midi. 2860 m.	(*) Puy de Dôme. 1467 m.	(*) Clermont. 388 m.	(*) Zi-Ka Wei. 7 m.
Pressure mm.	612	460	552	656	744	780
Corresp. temperature C°.	—4.7	—11.3	—4.8	1.8	— 8.9	— 3.5
Pressure mm.	574	434	522	622	710	758
Corr. temperature C°.	—23.3	—28.0	—14.2	—4.2	9.4	13.4
Diff. C° — for 1 mm.†	18.6	16.7	9.4	6.0	—11.3	—16.9
Pressure	0.48	0.62	0.31	0.19	—0.33	—0.77

Mr. Hazen finds but 21 instances of a noticeable inversion of the temperature between Burlington and Mt. Washington during the passage of 160 high areas over the summit, and finds this "a very small percentage." Now, I must remark that, with the large rate of decrease of the mean temperature between Burlington and Mt. Washington, even in winter, and the great difference of height, inversions of temperature must be seldom experienced, much rarer than in Europe. *I would ask Mr. Hazen how often are inversions of temperature experienced during the passage of cyclones or midway between cyclonic and anticyclonic areas?*

Dr. Hann, in the above-mentioned work, gives a calculation of the temperatures on the mountain stations of Sonnblick, Säntis and Ober, and some stations in the valleys, according to

* Mean of winter.

† Minus sign shows the temperature to be lower with higher pressure.

the distribution of pressure at sea-level. *The result for the winter is, the highest temperatures on mountain peaks are experienced during the highest pressure at sea-level,* the lowest during pressures very near to the mean (761–765), and somewhat higher temperature during the passage of cyclones. Mr. Hazen remarks that these results contradict the former results of Dechevrens and Hann, and show no effect at all corresponding to the change of pressure.

It seems to me that they show such an effect, especially if considered together with the other conditions of the atmosphere. It is necessary to state here that in the case of the relation of temperature and pressure on mountain-tops during cyclones and anticyclones, Hann and Dechevrens differ. The former considers the high temperature on mountain-tops during winter anticyclones as an established fact, while he does not consider a low temperature on mountain-tops during the passage of cyclones an established fact, nor as a necessary condition of the physical properties of the air. Dechevrens insists on the latter conditions.

I am of the opinion of Hann. The high temperature on mountain-tops during anticyclones is the more remarkable as it is accompanied by a small amount of cloud, that is, by conditions favorable to radiation and to a lower temperature in winter. Thus in the case cited by Dr. Hann we have

Mean pressure at sea-level—winter	750.7	763.8	775.9
" temperature at 7 A. M. on Sonnblick,	—13.2	—17.4	—12.3
" cloudiness	7.4	6.4	1.4

Another example is given by the observations on the Puy de Dôme at 6 A. M., mean of 9 days—December 20-28, 1879—when the mean pressure at sea-level was above 780 mm.

	Puy de Dôme.	Clermont.
Mean temperature	3.8	—13.2
" relative humidity	38	87
" amount of cloud	0	0

This high temperature cannot be caused by the sun's rays, as the sun is considerably below the horizon at 6 A. M. in that latitude in December. It is dynamical heating caused by the excess

of air in the centre of an anticyclone. It is Dr. Hann's merit to have been the first to explain the facts of "inversion of temperature," known long ago.

In the article of his cited above he has not explained the cold at the Sonnblick, with medium pressure at sea-level. It is very often cold on mountain-tops in winter: (1) in the rear of cyclones; (2) during and somewhat after the passage of cyclones to the south of the place of observation (in the northern hemisphere). The cold is caused by cold winds from N. W. to E. (in Europe); it is cold also in the valleys, but more so on mountain-tops, as the air is cooled by ascending. I have contrasted this kind of cold weather type with that experienced during anticyclones. In the latter case the valleys are cooled by radiation on the spot, the mountains are warmed by descending air-currents, and the temperature is higher than the mean with clear, calm weather. When the cold is brought by cold winds, the decrease of temperature is greater than the mean. So it was in the period of December 9–22, 1874, in Switzerland. The decrease of temperature with elevation was 0.7 C° for 100 m. between Neuchatel and Chaumont (mean of December 0.24), and 0.6 between Altstötten and Göbris (mean of December 0.07).*

In the eastern United States the cold weather is more frequently of the latter type than in Europe, and less frequently is it caused by radiation on the spot in the centre of anticyclones. The reasons are: (1) the greater strength of winds in the rear of cyclones; (2) their coming from a continental area; (3) the greater decrease of temperature with increase of latitude, especially in winter; (4) the more frequent passage, on nearly the same path, of cyclonic and anticyclonic areas and their greater rapidity. In Europe, on the contrary, anticyclones often remain stationary for many days, in some cases even weeks, and the vicinity of the Alps is the region of Europe where this happens most frequently. This causes the small decrease of temperature between the valleys and peaks of the

* *Zeitschr. f. Meteorologie*, 1883, p. 241 and following.

Alps in winter, the cold of the valleys and high temperature of mountains being of frequent occurrence. In the eastern United States the mean rate of decrease of temperature with elevation is considerably greater, the wind of weather where it is greatest, viz., cold, strong winds, being of frequent occurrence.

ST. PETERSBURG, April, 1888.

CORRESPONDENCE.

DIRECTION OF TORNADOES FROM CYCLONE CENTER.

To the Editors: In an endeavor to find some law for location of tornadoes, from the 7 A. M. daily weather bulletin, fifty tornadoes were taken as they occurred and location noted in relation to the 7 A. M. bulletin. One occurred in the low area, one northeast, five east, nineteen southeast, fourteen south, seven southwest, two west, one northwest; so I found no law here.

A high area lay in regard to the low area, north nine, northeast thirty-four, east thirty-four, southeast forty-one, south fifteen southwest fifteen, west twenty-eight, northwest twenty-three times. All the directions in which a high area lay were considered, so I found no law here. Yours truly,

J. F. LLEWELLYN.

MEXICO, MO., April 29, '88.

THE RELATION OF TORNADO REGIONS TO AREAS OF LOW PRESSURE.

To the Editors: My attention has been called to an article entitled "Tornadoes and Cyclones," by H. A. Hazen, appearing in the AMERICAN METEOROLOGICAL JOURNAL for April, raising the question as to who "first made mention of the fact that tornadoes do not occur at the center, but rather in the *southeast* quadrant of an area of low pressure."

Professor Hazen further says, "From time to time statements have been made regarding this subject, and Professor Ferrel, in 'Recent Advances,' page 327, considers that this point was first brought out in Professional Paper of the Signal Service, No. VII. On examining this, however, we find the author con-

siders that tornadoes occur in the *southwest* quadrant of a low area."

The following quotation from Professional Paper No. VII, prepared by me, page 27, embraces the word here referred to:

"In connection with the development of every tornado (which almost invariably takes place in the *southwest* quadrant of an area of comparatively low pressure) the wind previous to its inception has been found blowing from a southerly quarter south of the central area of barometric minima, and from a northerly quarter north of the central area, for a period of from five days to two weeks.

"As illustrating this point, the accompanying map, marked 'A,' has been prepared. This map displays the conditions of temperature, barometer, and the wind direction in connection with the violent tornadoes of June 12, 1881."

Professional Paper No. VII was written in 1881–1882, but it was not published for distribution until 1884. The first edition had to be suppressed on account of many typographical errors, and they were not all eliminated from the second edition, one of which appears in the use of the word *southwest* where it should be *southeast.*

The map above referred to clearly illustrates the typographical error in the text.

Professor Ferrel, not deficient in scientific acumen, perceives the true meaning, as is shown by the following extract from "Recent Advances in Meteorology," page 327:

"It is now known from Finley's researches (Professional Paper No. VII) and tornado charts, that the positions of tornadoes in cyclones have a certain relation to their centers, and that they are mostly found in a southeasterly direction from the center."

In the Signal Service Monthly Weather Review for June, 1881, I prepared the article entitled "Local Storms," and the accompanying chart illustrating it.

The following extract is made from my discussion of this chart:

"Along the *southeastern edge* of this area and northward to parallel 40 the winds were from south to southwest, with temperatures ranging from 80° to 100°. Over Iowa, Nebraska, and

extending thence into Colorado and Wyoming, a belt of north to northwest winds prevail, with temperature ranging from 63° to 78°. Confined to a region of country having a width of about 500 miles a thermal difference of 37° was presented along the line of conflict between the opposing northerly and southerly winds. Bounded by the distinctive features of these atmospheric currents it is found that Kansas, Missouri, Iowa, and Nebraska, but more particularly the two former, come within the region of violent wind storms and tornadoes."

In a pamphlet entitled, "Tornadoes, their Special Characteristics and Dangers, with Practical Directions for the Protection of Life and Property," prepared by me, and published at Kansas City, Missouri, in June, 1882, is to be found the following extract:

"From a study of the Weather Map it has been found that the formation of what is termed a barometric trough or elongated area of low pressure (where the barometer stands below the normal for that region at the hour of observation) precedes the occurrence of tornadoes in the Lower Missouri Valley or adjoining States to the *south* and *east.*"

Precisely the same language was employed in an article which I prepared on the subject of tornadoes and which was published in the Kansas City *Review of Science and Industry* for July, 1882, page 151.

On December 22d, 1883, the manuscript of Signal Service Notes, No. XII, went to press, and on January 17th, 1884, the entire edition was printed. On page 7 of this paper the relation of the region of tornado origin to the location of the accompanying area of low pressure is clearly stated as being to the "*south* and *east*" of the latter.

In May, 1883, I published three articles on "Tornado Studies" in *The Commercial*, printed at Ypsilanti, Michigan, in one of which I made the statement that "tornadoes almost invariably occur to the *south* and *east* of a barometric trough, or an elongated area of low pressure."

As Prof. Hazen has been attached to the Signal Service Bureau since May, 1881, and is naturally of an inquiring turn of

mind, the preceding information, which for the most part is of the official records, should not have escaped his attention, to say the least.

If the facts as cited were really known to him, his position in the case is all the more unfortunate.

While other persons may have mentioned the matter incidentally, or were aware in some instance that tornadoes occurred to the *south* and *east* of the principal storm centre, I believe that I can rightfully lay claim to whatever credit may be due to the first announcement of the general truth as deduced from the results of special investigation.

The above facts clearly show that the discovery was made known by me long before the occasion on which Prof. Hazen claims priority, viz.: *March 30th, 1884.*

JOHN P. FINLEY, Lieutenant, Signal Corps.

Postscript.—In the May number of this Journal, page 43, Prof. Hazen recedes from his first position (see April Journal, page 584), wherein he assumes the attitude of discoverer and promulgator of the law that tornadoes occur in the south and east of an area of low pressure, and now occupies another position from which he makes the announcement that his priority exists in the claim of "definite mention and emphatic calling attention" to this particular law of tornado development.

This is too low a standard by which to judge my rights in the matter, and moreover is an extraordinary position to occupy in the face of what Prof. Hazen ought to know as the unmistakable language of my publications concerning the location of the region of tornadic action.

Of all the ways of retreating from an indefensible position, the method adopted by Prof. Hazen is both unique and original.

Prof. Hazen should not attempt to divert attention from the point at issue by referring to the *causes* of tornado formation. He makes a claim which he is not entitled to, and he is well aware of his untenable position. It is a simple question of fact, not of theoretical discussion, where one or the other wins by the force of argument and the weight of formulæ.

Did Prof. Hazen *first* publish to the world the fact that tor-

nadoes occur, not at the centre of the low pressure in the general storm prevailing at the time, but to the *south* and *east* of such region? He did not, and the records are conclusive against him.

This is the question at issue and one not easily dodged in this particular case.

J. P. F.

CURRENT NOTES.

HILL ON ANOMALIES IN WINDS OF NORTHERN INDIA.—In addition to the admirable series of Memoirs published by the Indian Meteorological Service, there are valuable contributions made by the officers of the service to the Philosophical Transactions of the Royal Society, of London, among which we may mention a recent essay by S. A. Hill, on "Some Anomalies in the Winds of Northern India and their Relation to the Distribution of Barometric Pressure," (Phil. Trans., Vol. 178, 1887, pp. 335–378). The paper is of particular interest to American readers by reason of its essential point being an amplification of Espy's explanation of the diurnal increase in the velocity of the wind, which Mr. Hill applies most ingeniously, although he attributes it to its re-discoverer, Dr. Köppen.

The anomaly in question is the occurrence of westerly winds on the desert plains of Northern India, in May and other hot months, which blow against the direction of the local baric gradient, and with a strength disproportionate to its value. The published observations leave no doubt on this apparent contradiction of a generally well established meteorological law, and search was therefore made to discover the cause of so remarkable an exception. It seems that the abnormal winds blow chiefly in the daytime, and that they are very hot and dry. Some years ago, Mr. Blanford suggested tentatively that they might be due to the sudden expansion of the lower air during the hours of rapid increase of temperature; but in such case, they would blow with and not against the local gradient. Mr. Blanford also made in brief form the suggestion now followed up by Mr. Hill, to the effect that the time of occurrence and the

abnormally low humidity might be explained by the descent of air from aloft, in virtue of the vertical interchange of lower and upper air at times and in places where the vertical decrease of temperature is exceptionally rapid. Mr. Hill first establishes the facts of the case beyond question, and shows that the source of the winds cannot be looked for in the region whence they come, because the absolute humidity of the atmosphere in that direction is greater than that of the winds themselves. It also appears that the winds are most distinct during the hottest hours of the day, and this at the season when the high-level stations show the most rapid vertical decrease of temperature of the year. Their occurrence is therefore just in the hour and season that would be most marked by vertical interchanging currents, but it remains to account for their direction. To do this, Mr. Hill calculates from all available observations the distribution of mid-day pressure at a height of 10,000 feet, and draws the isobars for this high-level surface for the months of January, May, July and October. In May, there is at this level a distinct gradient to the north-northeast, on which the upper winds would flow to the east. The height of 10,000 feet was chosen because, judging by the noon-day rate of vertical decrease of temperature, the interchanging currents might be expected to extend to an altitude of about this measure. Admitting, then, that there are such currents at the time in question, the descending air would tend to maintain the direction that it had in the upper current, and would thus give rise to westerly surface winds, whose humidity would be very low, because of their descent from the upper air. The occurrence of dust-whirls, the frequent piling up of cumulus clouds and the occasional occurrence of thunder-storms at the time of the hot westerly winds, all testify to the actuality of the vertical currents; and the observed phenomena of the hot westerly winds agree so fully with what might be deduced from the conditions brought forth in the descent of the upper current that it is safe to conclude that the one is caused by the other. Hill summarizes his work as follows: Köppen's (Espy's) hypothesis of convective interchange between the upper and lower strata

of the atmosphere is probably the true explanation of the hot westerly winds. First, because the vertical distribution of temperature is such that convective action must take place; second, because the diurnal variation of the intensity of these winds and their characteristic dryness suggest such an origin for them; and third, because the distribution of pressure at 10,000 feet above sea-level in May is such as to produce winds of the observed direction.

It would be interesting to look for similar winds on the plains of Texas in the Summer months. W. M. D.

Die Regen Verhältnisse des Russischen Reiches; V Supplement-band zum Repertorium für Meteorologie, by Dr. H. Wild, Director of the Central Physical Observatory, St. Petersburg, 1887. pp. 119 + IV. + 95 + CCLXXXVI. (With an atlas.)

In this volume Prof. Wild has done for the Rain observations in the Russian Empire, what he had previously done for the Temperature observations in the I Supplementary Volume of the "Repertorium" series.

Wesselowsky's work on the climate of Russia gave the rainfall for 62 places, embracing a total of 529 years of observation for a period ending with 1851. Wild's work gives the data for 450 stations for the time ending with 1882 and embracing 3112 years of observation; some few of the stations lying outside of the limits of the Russian Empire. Much of the labor of the work was borne by Mr. E. Wahlén, who was, according to Prof. Wild's statement, engaged several years on the work. It is possible to give here only a short account of some of the points considered in this memoir. The author takes up:

I. The disturbing influences in measuring Precipitation and counting the Days with Precipitation.

II. The yearly march of the Precipitation.

III. Changeability of Precipitation.

IV. Secular variation of Precipitation.

V. Maximum Precipitation in 24 hours.

VI. Geographical Distribution of Precipitation in the Russian Empire.

APPENDIX.

I. Alphabetical Index of Stations.

II. Reference Sources.

III. Tables.

a. Monthly amount of Precipitation in mm.

b. Number of Days with precipitation in general and with snow.

c. Max. of the amounts of precipitation during 24 hours, given in mm. for 27 places.

After a careful consideration of the elevation of the rain gauges above the ground for the stations under discussion Professor Wild decided to make *some* reductions to a common level of 2 meters above ground. He gives the following table for obtaining the annual amounts from the observed values:

Elevation in Meters.	1	2	3	4	5	6	7	8	9	10
	1.030	1.000	0.975	0.953	0.933	0.916	0.901	0.887	0.873	0.859
Elevation in Meters.	11	12	15	20	25	30	35			
	0.846	0.833	0.799	0.754	0.725	0.708	0.700			

Most of the values however are given as they were observed, as the kind of exposure was considered to have more effect in these results than the height above ground at which the rain gauge was mounted.

In the determination of the frequency of days with precipitation different writers adopt different ways of counting, and Prof. Wild has carefully compared the results obtained by counting days including those on which precipitation was perceptible to the observer, and by counting those days when the precipitation was 0.1 mm. or more. The tables given in this connection will be very useful to meteorologists for reducing average results frem one system to another; they include observations made at 12 selected places in Russia and all the climates are represented.

A careful distinction is made between the general observations of rain and the observations where care is taken to measure the amount of precipitation. For instance they have a record showing the rainy days at St. Petersburg during 128 years,

but the measures of amount embrace only a period of 69 years.

In the tables of mean monthly and mean annual precipitation, we find in column 1 the current index number of the station; column 2 the latitude; column 3 longitude; column 4 the elevation of the station above sea level; column 5 the name of the station; columns 6–17 the mean monthly precipitation; column 18 the mean annual precipitation; column 19 the number of years and months of observations and the particular years during which these observations were made.

The corresponding table showing the number of days with precipitation is also important. These two being of the greatest interest to students of the Russian climate.

The table of days having snow fall shows very forcibly the high latitude of the country, for many of the stations have a goodly number of days with snow-fall in each month except July and August, and there is no month when snow did not fall at some station, although there was no single station where the snow fell every month. Several stations were free from snow-fall only one month of the year.

The intensity of precipitation is obtained by dividing the total amount of precipitation for a period by the number of days of precipitation during that period. Within the limits of the Russian Empire the mean monthly intensity of precipitation varies between the limits 0 and 25 mm. (per day), and for the mean annual intensity of precipitation the limits are 26 mm. and 17.4 mm.

About 45 stations were selected for the discussion of such questions as the probable error of the monthly and annual means; the number of years necessary in order to reduce these errors to 1 mm. for the monthly and 10 mm. for the annual amounts in per cents. of these amounts, etc.

Professor Wild has selected a few stations for which he has investigated the secular variation of the precipitation by taking the mean and getting the residuals for each year and conbining these residuals also in 5 year groups. Barnaul showed a 42 year period with max. in 1840 and 1882 and min. in 1863, with an amplitude of 270 mm. which is considerably in excess

of the mean annual rainfall (257 mm.) Other stations west of this show a slightly shorter period, the max. occurring 1840–1844, the min. at about 1863 and the second max. from 4 to 9 years earlier than Barnaul.

Tables of the maximum amount of precipitation during 24 hours show a tolerably well defined annual period; St. Petersburg had a max. of 59 mm. and few places have an excess of 100 mm. (Pekin had 251 mm.) The mean max. for all the years at St. Petersburg was 28 mm.

The table of 457 stations showing the average precipitation for the season, is of value for comparison with the results for other lands which are frequently published in this form; and in this same form, Director Wild has given short tables of results in Norway, Denmark, Germany, Austria, Turkey, Japan, India and some Polar stations. These tables are used in the construction of the charts contained in the atlas accompanying the work.

In the appendix a short space is devoted to each station, in which is given notes concerning the establishment and continuance of the stations, the observers, and in many cases short tables of particular investigations which may have been made of the rainfall at these stations. For some well-known stations, such as St. Petersburg, these notes are of great interest.

The main part of the appendix is taken up with the statistics of rainfall for each station, where the amount for each month of observation is given, with the means for the months and each year. This same data is given for the number of days with rain and snow.

Another very important part of the Appendix is a table giving for a great many stations the maxima of the amount of precipitation during 24 hours for each month of the period of observation, or for as long a period as was accessible. (We notice that at Pekin in July, 1848, there was a maximum rainfall of 250.7 mm., or nearly 10 inches in 24 hours.)

The atlas accompanying this work is made up of six charts; these show the Curves of Equal Rainfall for the Year, Fall, Winter, Spring, and Summer, and the number of days with Precipitation during the year. These charts are beautifully

done, and show us plainly the Relative Rainfall in northern Europe and Asia.

An examination of the chart for the year shows that in European Russia the Baltic coast has 60 cm.; the important country extending from the German frontier to the Don, and lying between the 50° and 60° parallels, has from 50 to 60 cm.; and a large tract lying along the 60° parallel and spreading several degrees each side, and extending from 40° E. long. to 100° E. long., has from 40 cm. to 50 cm. (except a narrow tract a little east of Katharinenburg, which has from 30 cm. to 40 cm.). From the upper course of the Don River to the northeast shore of the Caspian Sea there is a gradual decrease from 50 cm. to 10 cm. For northern European Russia there is a decrease from lat. 62° toward the north, a minimum of 20 cm. being found west of the mouth of the White Sea, most of the coast having from 20 to 30 cm. of rainfall. On the east coast of the Black Sea is a maximum of 200 cm.; but the gradients are steep, and the 50 cm. line is not far distant.

Most of Siberia is dry. The 40–50 cm. belt already mentioned lies near the center, and the rainfall decreases in all directions to the 20 cm. curve (except in the west, where after a slight fall there is an increase, and on the east central portion, where the minimum does not quite reach 20 cm). On the eastern coast the increase is very rapid up to 100 cm., but the arctic coast lies within the 20 cm. curve. A few degrees south of Irkutsk there is a vast tract having less than 20 cm., but the absolute minimum seems to be the country around the Aral Sea, where the rainfall is within the 10 cm. line. Near the limits of the map we find a 200 cm. curve in Japan, and also in northern India.

Lack of space prevents describing the curves of the number of days with precipitation, and I will only mention that near St. Petersburg they have 160 rainy days in a year, and south of the Sea of Aral they have less than 30 days. F. WALDO.

BLANFORD ON THE RELATION OF RAINFALL TO FORESTS.—The question of the relation of rainfall to forests has long been discussed, but it is seldom that quantitative measures of precipita-

tion have entered the problem in such a way that they could be employed toward its settlement. Just at present, when the allied question of the variation of rainfall on the western plains in consequence of their cultivation is exciting public interest, a contribution to the discussion from the pen of one so competent as Mr. Henry F. Blanford, meteorological reporter to the government of India, has a particular interest. His article is "On the Influence of Indian Forests on the Rainfall;" it is published in the Journal of the Asiatic Society of Bengal, Vol. LVI, Pt. II., 1887.

Mr. Blanford first refers to the generalizations of Woeikoff, to the effect that the forests of a country increase its rainfall, in evidence of which the eminent Russian author appeals to the contrast afforded by the Assam rainfall with that of the Gangetic valley-plain, in about the same latitude and the same distance from the sea; the latter being a broad field, generally under cultivation, while the former is extensively covered with forest. Blanford is not ready to accept this argument to Woeikoff's conclusion, and attributes the difference of rainfall in these two localities to other physical conditions than their quantity of tree-covering. He thinks that a satisfactory solution of the question must await the production of a series of rainfall records from a single region, which is forested for a time and then deforested—or *vice versa*—and as a contribution to such a series of records he quotes the results of observations in a part of the central provinces of India, south of the Satpura range, where five-sixths of the whole area of 61,000 square miles have been greatly deforested in the last twenty years, and where a good number of well-made rain measurements can be appealed to under these two conditions. The records from 1865 to 1875 were made during a time of reckless waste of forests by clearing and by fires; but in the succeeding ten years, the suppression of these wasteful methods was taken systematically in hand by the government, and a more or less dense growth of young forest has grown up. During the second period, the rainfall has progressively increased until the mean for fourteen stations appears to be 20 per cent. more than it was for the first

ten years; while there has been a decrease of about 6 per cent. at seven stations in the surrounding districts, where the forests have not changed materially.

Another example is given from a forest produced artificially in a dry region with the assistance of irrigation. The records for seventeen years within this forest show an excess of 6 per cent. over the probable unforested rainfall of the station, as computed from the records of two adjacent stations outside of the forest. A third example is given of gauges inside and outside of a forest area, on the plan pursued by Ebermeyer in Bavaria, where for a short period the records show no significant difference.

Blanford summarizes his results as follows: While not considering the result as established on the point at issue, still, the evidence as far as it goes favors the idea that forests increase the rainfall. The evidence is not rigorously conclusive, and it must be admitted that in no case has it been guarded by those special precautions, which are demanded by strict scientific inquiry; but there is no reason to believe that the records are not as trustworthy as observations made under the the general supervision of intelligent and educated men usually are. It justifies the view that the long suspected influence of forests on rainfall cannot now be regarded as a question of equally balanced probabilities.

Mr. Blanford is so competent an observer and cautious a writer that his opinion on this mooted question is entitled to much weight. The matter is one of great practical importance in this country, and having heretofore been strongly disposed to take the other view of the relation under discussion, I am particularly interested in this note. As far as our own records go, they do not seem to be good enough to settle the question. The argument in the west is affected inevitably by the interests of most of those engaged in it, whereby a greater weight must be unconsciously given to evidence leading to the desired result. The conclusion that the Plains will become susceptible of occupation as they are cultivated is so agreeable that untrained observers will be led by their preference to their conclusion; they will neglect evidence that is against them while they dwell

on anything that is in their favor. The general belief among western settlers is that the question is decided, and they are characteristically ready to accept insufficient explanations of the result, such as the influence of railroads and telegraph lines in affecting the electrical condition of the air and thus changing the distribution of rainfall, while the greater number of careful students of the matter admit that the evidence concerning it is still inaccurate and insufficient.

The inaccuracy of one of the most important records in the west, as lately shown by Curtis, is a case in point. The change in the position of gauges, brought forward by Whitney, is another; under the orders of the Surgeon-General, the gauges were first set at a greater height above the ground than that recommended in later years under another regime, and it is well known that the amount of rain collected decreases with the height of the gauge over the ground, on account of the disturbing effect of wind eddies caused by the support of the gauge. The generally unscientific character of the early observations is also much against them. The method employed by Harrington cannot be regarded as at all conclusive, because it depends on too inaccurate data; the lines of equal rainfall on the Plains, especially as drawn on Blodget's charts, are not well enough defined to be accepted in evidence; observations were then too few to determine them.

The whole question must be kept open until accurate and comparable data are collected. W. M. D.

EARTHQUAKES.—Commander S. H. Baker, U. S. N., commanding U. S. store-ship "Monongahela," Coquimbo, Chili, reports a shock of earthquake at 9:30 P. M., Greenwich mean time, January 4; duration of shock, 35 seconds.

Captain Crasso, British brigantine "Diadem," experienced a moderate earthquake shock March 1, 9:15 P. M., civil time, latitude 26° 02′ N., longitude 63° 19′ W. The duration of the shock was from 12 to 15 seconds, and the sensation was as though the vessel had grounded upon a reef or struck some obstruction. The night was clear and pleasant; wind from north, with a long heaving swell from the same quarter.—*Pilot Chart.*

CIRCULAR

CONCERNING

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Recognizing the high importance of a fuller knowledge of TORNADOES, and believing that a combined effort will much advance our knowledge, we offer for general competition the following prizes:—

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The subject of Tornadoes is a large one, and it is not the intention of the JOURNAL to limit writers in their treatment of it. They may discuss the subject in all its branches, or may discuss any part of it. The following suggestions are made of the division of the subject, and the essays may be devoted to any or to all of these divisions:

1. Descriptions of individual Tornadoes are still of importance, especially when accompanied by careful meteorological observations during, before, and after the Tornado; and a study of the relations of the tornado to general weather conditions prevailing at the time. A study of the paths of old Tornadoes as shown by the overturn of trees in forests would be of interest.

2. The relations of Tornadoes to life and property, including the prediction of them in general, or automatic prediction for a short time

in advance for any particular place, the means of protection from them and Tornado insurance.

3. The study of aerial Tornadoes which do not reach the ground, would be of especial interest.

4. The theory of Tornadoes, including an account of the progress of our knowledge on the subject.

In judging the Essays sent in, especial attention will be paid to their scientific value and to their originality. Three independent and capable judges will be selected, by whom the awards will be made as soon as practicable after the close of the competition.

The essays must be in English, or must be accompanied by an English translation, and they must contain not less than 2,000 nor more than 5,000 words. They must be signed by some mark, symbol or *nom de plume,* and accompanied by an envelope addressed with the same mark, symbol or *nom de plume,* and containing the real name and address of the writer. The awards will be made by the judges without a knowledge of the names of the authors.

In order to exclude candidates without merit, and as a guarantee of good faith on the part of those who do compete, a deposit of five dollars in American money, or its equivalent, will be required of all candidates. This money must accompany the essay and be inclosed in the envelope containing the real name and address of the author. An equivalent for it will be given in subscriptions for the JOURNAL—two and a half years for home, or two years and four months for foreign candidates.

The successful essays are to become the property of THE AMERICAN METEOROLOGICAL JOURNAL, in which the results of the awards will be published.

During the time the competition is pending, important papers on Tornadoes will be published in this JOURNAL, the object of which will be to represent the present state of our knowledge on the subject. Many articles and notes have been published on this subject in previous issues of the JOURNAL.

The competition will be closed on July 1st, 1889, and all essays reaching the editors after that time will be excluded from competition. Essays may be sent to either Mr. Rotch or Mr. Harrington; inquiries for farther information should be addressed to Mr. Harrington.

MARK W. HARRINGTON,
Director Astronomical Observatory, Ann Arbor, Michigan, U. S. A.
A. LAWRENCE ROTCH,
Proprietor and Director of Blue Hill Meteorological Observatory, Readville, Massachusetts, U. S. A.

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A. LAWRENCE ROTCH,
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